SHORT COMMUNICATION

Intradepartment scientific collaboration in Journal of Research in Medical Sciences: A co-authorship study

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Background: This study aimed to use social network analysis (SNA) indicators and clique analysis to investigate collaboration between different departments and research centers in Journal of Research in Medical Sciences (JRMS) in 2012–2016. **Materials and Methods:** The study was a scientometric study using micro- and macro-indicators of SNA to investigate the performance of departments and research centers in JRMS. The population consisted of 1073 articles published in JRMS in 2012–2016. Ravar Matrix, UCINET, and VOSviewer software were used for data analysis. **Results:** According to the productivity and triple centrality indicators, "Department of Epidemiology and Biostatistics," "Department of Pathology," and Department of "Internal Medicine" allocated the first three ranks. Analyzing the cliques of co-authorship network for departments and research centers showed that this network consists of 19 cliques with at least 7 members in each clique. Furthermore, only 30 nodes (8.90% of all nodes in the network) had the presence in minimum clique size of at least 7. **Conclusion:** Given the importance and position of scientific collaboration in medical research and its effect on other performance indicators such as efficiency, effectiveness, and number of citations, it is necessary for policy-makers to propose new strategies for improving scientific collaboration.

Key words: Clique analysis, intradepartment collaboration, Journal of Research in Medical Sciences, social network analysis

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INTRODUCTION

Today, scientific collaboration is no longer a special consideration and has instead turned into a necessary part of scientific research.[1] Scientific collaboration means cooperation between different researchers and research centers to achieve common aims and improve scientific production. In general, these collaborations can be categorized into between or within forms and also based on their spatial scale. These two types of collaboration are shown with intra- and inter-prefix, respectively.[2] For example, collaboration between different departments is called intradepartment collaboration while collaboration in a certain department is called interdepartment collaboration.

The changes of scientific production behavior worldwide and exponential increase in the number of multiauthor papers in the last decades are obviously apparent.[3] Currently, there is a consensus in the scientific community, stating that this increase in multiauthored articles is the sign of increased scientific collaboration,[4,5] and scientific sociology is currently paying increased attention to the study of scientific networks, especially co-authorship networks, as the most common forms of scientific collaboration.[6] Social network analysis (SNA) is a method for analyzing the

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interactions between groups or actors present in these networks. Therefore, the current study aimed to use SNA indicators to provide a complete picture of intradepartment collaborations in different fields in Journal of Research in Medical Sciences (JRMS) during 2012–2016. It is also possible to use clique analysis to identify similar behavioral patterns and similarities between departments and research centers as well as departments and research centers with strong connections to each other. Since medical experts deal with complex and multidimensional problems such as health and diseases in society, cooperation among departments and research centers offers advantages such as reduced financial costs and using the knowledge of different experts and leading to improved productivity. Publication of the studies carried out through intradepartment collaborations in JRMS can expand the audience and provide more visibility by the experts in different areas that both influence its effectiveness on the scientific society.

MATERIALS AND METHODS

The study was a scientometric study using micro- and macro-indicators of SNA. The population consisted of 1073 articles published in JRMS in 2012–2016. To create the collaboration network of departments, each article was separately loaded in a computer and affiliation of its authors was extracted. Then, the organizational title of departments and research centers was normalized. Co-authorship matrix of these institutes was created using Ravar Matrix software (version 2, Ravar Matrix, Yazd, Iran).[7] To create and analyze the co-authorship between authors, UCINET (version 6.463, UCINET, Harvard, MA)[8] and VOSviewer[9] software (version 1.5.4, VOSviewer, Leiden University, Leiden, Netherland) was employed. In this study, collaboration network of departments and research centers in JRMS between 2012 and 2016 was investigated using macro- and micro-level metrics. Macro-level metrics such as density, clustering coefficient, mean distance, network diameter, network components, and network clustering were evaluated. The study also investigated the performance of each department and research center using centrality and collaboration indicators. Productivity indicator shows the number of articles published by authors with certain affiliations in JRMS between 2012 and 2016 while degree centrality shows the number of co-authorships of authors affiliated with a certain department or research center with researchers from other centers or departments. Betweenness centrality of a department shows the number of times that the department is connected to other department using the shortest possible link in the network. Closeness centrality of a node is the shortest possible link between that node and other nodes in the network. Density metric is the ratio of the connections present in the network to the total possible connections and has a value between 0 and 1. Clustering coefficient is another metric which shows the trend of departments and research centers present in the network for forming different clusters through co-authorship; it is also between 0 and 1. The network diameter metric shows the largest distance between nodes in the network. A component is a set of nodes (departments and research centers), in which every node is connected through a direct connection (co-authorship) or a chain of connections (co-authorship network) to other nodes. In other words, each node of a component is connected through a direct connection or through several connections to other nodes in the same components. The details of the indicators have been described in Zare-Farashbandi *et al*.[10]

RESULTS

Assessments showed that co-authorship network of JRMS derived from the activities of 337 departments for a total of 1950 collaborations. Network analysis based on macro-level metrics showed that the density metric for co-authorship network of departments and research centers in JRMS is equal to 0.012. In other words, only 1.2% of potential relations between departments and research centers were actualized which show open social relations and low network coherence. The clustering coefficient for this network was equal to 0.37 which means that if two departments or research centers, A and B, have separate co-authorships with node C, there is a 37% probability that A and B departments will have co-authorship relations in the future. The results also showed that the average distance between nodes in co-authorship network is 2.836. Based on these results, each two departments or research centers in this network are connected to each other with an average of 2.8 intermediaries. The network diameter metric shows the largest distance between nodes in the network. This metric is equal to 6, showing that departments and research centers with the largest distance from each other have a distance of 6 nodes. This study also investigated the components of co-authorship network of departments and research centers. This co-authorship network consists of a total of 44 components. The main and largest component includes 277 nodes which is a total of 82.2% of all the nodes in the network. There are also 29 isolated components with only one node each without any co-authorship with other departments or research centers [Figure 1].

The cluster analysis of co-authorship network of departments and research centers in JRMS showed that this network consists of 77 separate clusters. Cluster 26 containing the Department of Epidemiology and Biostatistics and cluster 21 containing the Department of Pathology are the most important clusters in this network. Investigating the collaboration between departments and research centers in

Table 1: Superior departments and research centers based on production, collaboration, and centrality

Department	Productivity	Collaborators	Department	Degree centrality	Department	Betweenness centrality	Department	Closeness centrality
Department of Epidemiology and Biostatistics	67	92	Department of Epidemiology and Biostatistics	161	Department of Epidemiology and Biostatistics	11157.77	Department of Epidemiology and Biostatistics	20,703
Department of Pathology	51	59	Department of Internal Medicine	102	Department of Pathology	6005.31	Department of Internal Medicine	20,741
Department of Internal Medicine	47	22	Department of Pathology	90	Department of Internal Medicine	4368.14	Department of Pathology	20,750
School of Medicine	40	23	Department of Pediatrics	87	Department of Pediatrics	3952.96	School of Medicine	20,757
Department of Neurology	32	11	School of Medicine	85	Department of Community Medicine	3658.95	Department of Pediatrics	20,767
Department of Cardiology	31	17	Department of Cardiology	70	Department of Neurology	3364.88	Department of Community Medicine	20,785
Department Of Community Medicine	31	15	Department of Community Medicine	68	School of Medicine	2713.14	Department of Cardiology	20,786
Department of Pediatrics	31	17	Department of Neurology	54	Department of Cardiology	2249.11	Department of Neurology	20,792
Department of General Surgery	24	13	Department of Endocrinology and Metabolism	47	Department of Pharmacology and Toxicology	1884.002	Department of Radiology	20,812
Department of Anesthesiology and Critical Care	22	8	Department of Gastroenterology	37	Department of Endocrinology and Metabolism	1725.32	Department of Endocrinology and Metabolism	20815
Department of Nephrology	22	13	Department of Nephrology	37	Department of Gastroenterology	1588.31	Department of General Surgery	20,820
Department of Psychiatry	22	6	Department of General Surgery	35	Department of Pulmonary	1548.60	Department of Gastroenterology	20,822
Department of Endocrinology and Metabolism	21	12	Department of Physiology	33	Department of Microbiology	1386.61	Department of Biochemistry	20,826
Department of Gastroenterology	16	12	Isfahan Cardiovascular Research Center	31	Department of Immunology	1285.77	Department of Microbiology	20,829
Department of Physiology	16	14	Department of Psychiatry	30	Department of Anesthesiology and Critical Care	1215.78	Department of Ophthalmology	20833
Department of Radiology	16	13	Department of Radiology	30	Department of General Surgery	1208.45	Department of Physiology	20,840
Department of Dermatology	15	10	Department of Community Nutrition	27	Department of Community Nutrition	1173.72	Department of Biology	20,842
Department of Community Nutrition	14	4	Department of Immunology	25	Department of Psychiatry	1153.11	Department of Obstetrics and Gynecology	20,842
Department of Obstetrics and Gynecology	14	7	Department of Nutrition	25	Department of Radiology	1088.31	Department of Nephrology	20,844
Department of Ophthalmology	14	12	Department of Microbiology	24	Department of Physiology	1005.74	Department of Psychology	20,844
Department of Microbiology	11	10	Department of Health Education	23	Department of Ear, Nose, and Throat	913.97	Department of Infectious Diseases and Tropical Medicine	20,848

Contd...

Table 1: Contd...

Department	Productivity	Collaborators	Department	Degree centrality	Department	Betweenness centrality	Department	Closeness centrality
Department of Radiotherapy and Oncology	11	9	Department of Obstetrics and Gynecology	23	Department of Ophthalmology	901.12	Department of Ear, Nose, and Throat	20,850
Department of Nutrition	10	4	Department of Pharmacology and Toxicology	23	Isfahan Medical Students Research Center	795.06	Department of Immunology	20,850
Isfahan Cardiovascular Research Center	10	5	Department of Ophthalmology	22	Department of Infectious Diseases and Tropical Medicine	635.74	Department of Anesthesiology and Critical Care	20,850

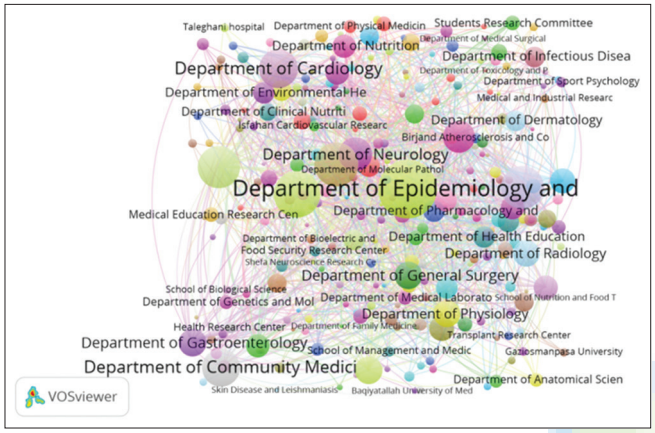

Figure 1: The co-authorship network of departments and research centers in Journal of Research in Medical Sciences

JRMS using productivity and centrality indicators showed in Table 1.

Clique analysis of co-authorship network of departments and research centers

In studies which analyze scientific collaboration networks, usually, subgroups of the network are also analyzed along with the network itself. One of the methods for identifying and analysis of dense and continuous subgroups in social networks is clique analysis method. A clique is a subgroup of the network with density of 1 in which each node is connected to all other nodes in the group. For example, in a social network of friends, a clique is a subgroup of people in which each member knows all other members. Clique is usually considered to be the most important indicator of societies in social networks where nodes have a large number of interactions with each other along with common characteristics, therefore increasing the speed of information flow between these nodes. In this study, the minimum size of 7 was used for clique analysis, and therefore, a total of 19 cliques were identified in the network [Table 2].

The results showed that only 30 nodes (8.90% of total nodes present in the network) belonged to cliques with at least 7 members and other nodes were members of smaller cliques [Table 2]. On the other hand, investigating clique-by-clique actor co-membership matrix of cliques in co-authorship network of JRMS showed that cliques 1&2, 1&8 2&3, 2&9, 3&6, 3&10, 3&16, 4&5, 5&6, 5&12, 6&17, 9&10, 11&12, 16&17, 16&19, 17&18, and 18&19 with a total of 6 overlapping members had the highest amount of similarity, while in 18 cases, there are no common nodes between cliques which means that nodes of these cliques had no scientific collaborations with each other.

DISCUSSION

The current study evaluated the collaborations between departments and research centers in JRMS between the years 2012 and 2016 based on SNA indicators and clique analysis. The situation of co-authorship network in JRMS based on macro-network metrics is as follows: the network with low coherence with small number of potential collaborative connections being actualized. On the other hand, the desire of departments and research centers for co-authorship is low. Low centralization of departments and research centers around certain powerful departments has led to disconnection and lowered centralization metric. One of the reasons for this low centralization is the naming method of departments and research centers so that departments and research centers with similar specializations use different names. This leads to creation of small co-authorship groups around various names instead of formation of large groups around a central node.

In productivity and triple centrality metrics, Department of Epidemiology and Biostatistics, Department of Pathology, and Department of Internal Medicine had the first three ranks. This means that these three departments are the most productive and collaborative groups present in the network. Researchers in these departments tend more toward collaborative and co-authorship works with researchers from other departments and research centers. Based on triple centrality metrics, it can be said that these departments have suitable locations in the network and are positioned at the shortest distance for scientific collaboration with other departments and research centers. This means

Table 2: Cliques in co-authorship network of departments and research centers of Journal of Research in Medical Sciences (at least 7)

Cliques	Size	Centers and Departments
1	6	Department of Biochemistry; Department of Cardiology; Department of Endocrinology and Metabolism; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Pediatrics; School of Medicine
2	6	Department of Cardiology; Department of Endocrinology and Metabolism; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Pediatrics; Department of Radiology; School of Medicine
3	6	Department of Cardiology; Department of Community Medicine; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Pediatrics; Department of Radiology; School of Medicine
4	6	Department of Epidemiology and Biostatistics; Department of Gastroenterology; Department of Internal Medicine; Department of Ophthalmology; Department of Pathology; Department of Pediatrics; School of Medicine
5	6	Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Ophthalmology; Department of Pathology; Department of Pediatrics; Department of Radiology; School of Medicine
6	6	Department of Community Medicine; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Pathology; Department of Pediatrics; Department of Radiology; School of Medicine
7	7	Department of Anesthesiology and Critical Care; Department of Cardiology; Department of Epidemiology and Biostatistics; Department of Obstetrics and Gynecology; Department of Pediatrics; Isfahan Cardiovascular Research Center; School of Medicine
8	7	Department of Biochemistry; Department of Cardiology; Department of Endocrinology and Metabolism; Department of Epidemiology and Biostatistics; Department of Pediatrics; Department of Public Health; School of Medicine
9	7	Department of Cardiology; Department of Endocrinology and Metabolism; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Nutrition; Department of Pediatrics; Department of Radiology
10	7	Department of Cardiology; Department of Community Medicine; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Nutrition; Department of Pediatrics; Department of Radiology
11	7	Department of Ear, Nose, and Throat; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Neurology; Department of Ophthalmology; Department of Pathology; School of Medicine
12	7	Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Neurology; Department of Ophthalmology; Department of Pathology; Department of Radiology; School of Medicine
13	7	Department of Cardiology; Department of Endocrinology and Metabolism; Department of Epidemiology and Biostatistics; Department of Internal Medicine; Department of Neurology; Department of Radiology; School of Medicine
14	7	Arak Health Center; Cardiovascular Research Center; Department of Cardiology; Department of Endocrinology and Metabolism; Department of Pediatrics; Department of Public Health; School of Medicine
15	7	Center for Research in Skin Disease and Leprosy; Department of Biology; Department of Cellular and Molecular Biology; Department of Dermatology; Department of Immunology; Department of Mycology and Parasitology; Department of Physiology
16	7	Department of Cardiology; Department of Community Medicine; Department of Internal Medicine; Department of Nephrology; Department of Pediatrics; Department of Radiology; School of Medicine
17	7	Department of Community Medicine; Department of Internal Medicine; Department of Nephrology; Department of Pathology; Department of Pediatrics; Department of Radiology; School of Medicine
18	7	Department of Community Medicine; Department of Internal Medicine; Department of Nephrology; Department of Pathology; Department of Radiology; Department of Radiotherapy and Oncology; School of Medicine
19	7	Department of Cardiology; Department of Community Medicine; Department of Internal Medicine; Department of Nephrology; Department of Radiology; Department of Radiotherapy and Oncology; School of Medicine

that these three departments are highly accessible to other nodes. The high closeness metric of these three departments shows their influence, centrality, and key role in distribution of information between other nodes in the network. A study by Mazaheri *et al*.[11] also reported similar results. Based on the variety of collaborators, "Department of Epidemiology and Biostatistics," "Department of Pathology," and "School of Medicine" had the largest number of collaboration with other departments. This shows the power of these three departments in connecting to other departments and research centers as well as transferring information through the co-authorship network. One of the reasons for the strong presence of "Department of Epidemiology and Biostatistics" in various indicators is due to the definite role of the researchers of this field as the statistical consultants in dissertations or other clinical studies. Furthermore, using multiple affiliations by some researchers has also improved the ranking of some departments and research centers.

In analyzing scientific collaboration patterns, it is necessary to consider the relation between the nature of the research and the amount of collaboration. Several studies have

proven that experimentalists tend to collaborate more than theoreticians, and theoretical works usually have lower number of collaborations compared to experimental works.[12] Even there are some differences in experimental works. A co-authorship analysis of researchers in the departments of "Biology" and "Chemistry" in York University showed that researchers in the Department of "Biology" had small number of collaborations in comparison with the researchers of the Department of "Chemistry."[13] Abramo *et al*.[14] showed that collaboration often happens in medical fields. Studies in medical fields require a large spectrum of specializations which oblige collaboration of different researches with different professions.[15] Studying research projects of the Ministry of University and Research in Italy showed that multidisciplinary projects make up only 11% of all projects. The highest trend for interdisciplinary studies belongs to clinical studies including biology and medicine.[16]

In studies analyzing scientific collaboration networks, usually, the performance of subgroups is also evaluated along with the network performance as a whole. Clique analysis is one of the methods for identification and evaluation of cohesive subgroups in social networks. Clique is usually one of the most important indicators of social networks in which members have a large number of interactions and common characteristics, and therefore, the flow of information between them is a lot faster. The results showed that only 30 nodes (8.90 of total nodes) had the presence in minimum cliques size of at least 7 and other nodes were part of cliques with smaller size. On the other hand, in 18 cases, there are no common nodes between cliques, meaning that these cliques had no co-authorship scientific collaborations with each other. Theories in the area of social networks suggest that formation of collaborative connections in social networks depends on common interests between nodes as well as cost and benefit of short- and long-term relations for nodes in the network. Since the presence of two nodes in a clique shows collaborations and common research interests between these two nodes of co-authorship network, researchers and policy-makers can use this information to prioritize scientific collaboration with departments and research centers in the same clique as their own or with departments and research centers closer to them in the co-authorship network. Without doubt, scientific collaboration with departments and research centers with common research interests can improve the quality and quantity of scientific productions.

CONCLUSION

Since social networks always grow through addition of new nodes and connections, it can be also said that departments and research centers with high productivity and centrality metrics play important roles in expansion and completion of co-authorship networks. Therefore, better collaboration between these departments and research centers and also attracting new research centers can help the network's growth and dynamism. Scientific collaboration can have short-term educational results for improving special projects such as group workshops and collaborative readiness audits and long-term modalities such as improved curriculum, experiential learning, and collaboration between graduate students in different fields.[17] The usefulness of this study can be investigated from two perspectives. First, due to the importance of JRMS in Iranian Medical Society, studying its collaboration network between various departments and research centers can play an important role in facilitating interdisciplinary and multidisciplinary studies in medical sciences. Budget cuts in research centers on the one hand and increased cost of medical studies on the other hand highlights the importance of collaboration between departments and had shifted the attention of scientometric researchers from collaboration among researchers to collaboration among departments and research centers. This means that the results of the current study can be the first step in identifying factors facilitating collaboration between departments and research centers at university, national, and international levels. Second, the results of studying possible collaborative relations between departments and research centers using different indicators such as scientific productivity, article impact, journal impact factor, and journal visibility at journal level can be used for improving or modifying the article acceptance process of the journal which can improve the reputation of the journal in scientific community.

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Conflicts of interest
There are no conflicts of interest.

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